CLINICAL IMPORTANCE OF THE MINIMAL CANCELLOUS DIAMETER OF LOWER THORACIC AND LUMBAR VERTEBRAL PEDICLES

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ABSTRACT :

Transpedicular spinal fixation is a widely used method in vertebral surgery, but it suffers from complications due to mismatches between the screw and pedicle. Therefore, information of minimal cancellous (MCD) and minimal external diameters (MED) of the pedicle is highly important for vertebral surgery. To determine these diameters and their ratios. 2.808 measurements of 1.404 pedicles of 702 human vertebrae were made from Th 11 to L5. We found that the mean ratio of MCD to MED was 72.2%. MCD to vertical diameter (VD) was 41.7%, and MCD to transvers diameter (TD) was 62.2% in all levels. We recommend that these results be considered prior to pediculer fixation operations and design of new implantable devices.

Key Words: *morphometry, thoracolomber, spine*

INTRODUCTION

Transpedicular spinal fixation has recently been the focus of increased attention in several instrutions throughout the world, but its safety and efficacy are still important question for orthopedic surgeons (3, 4, 6, 7, 8, 11, 12, 15, 16, 19, 22). For a reliable match between the screw and pedicle, it is necessery to know the minial external diameter (MED) and minimal cancellous (MCD) diameters of the isthmus part of pedicle (11).

In our previous research (6), we found a real minimal diameter that was different the vertical and transvers diameters. The smallest external and internal diameters of pedicle cannot be unquestinable determined by the imaging methods currently in use, direct measuremet excepted. Computed Tomography (CT) may give information about MED and MCD of a pedicle. To measure these diameters correctly, the sections must be made perpendicularly to the pedicle axis (9) and also must be taken at a narrowest part of the pedicle, but cannot be sure that two conditions are satisfied simultaneously. Even if this can be realized, it can be quite difficult to be determine to screw size each pedicle using CT, because a number of screws have been inserted into the pedicle during operation. Therefore, this would not be practical for daily routine vertebral surgery. We then suggested that MED be estimated using the ratio of vertical or transverse diameters to referance minimal diameters each level. The proportion of cortical and cancellous bone in pedicles varies at diferent levels of the vertebral column (13). However, there is a lack of information in the literature on ratios of MCD to vertical diameter (VD), transverse diameter (TD), and MED. This study was undertaken to determine this ratios for each level of pedicle.

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MATERIALS AND METHODS

In this study, we evaluated 702 human vertebrae obtained from the Ankara Municipality Graves. Bones with congenital anomalies, incomplete vertebrae, and children's bones were exculted. Age and sex of the vertebrae were unknown.

Th 11, Th 12, and L5 wee differentiated using the classical methods (10, 20, 21). For differantiation of the renaining lumbar vertebrae the method Güzel et al. (5) was used. Vertebrae were group into Th1, T12, L1, L2, L3, L4 and L5. To ensure consistency, all measurements were made by the some observer throughout the study.

Two pedicles of the vertebrae were cut on the axis of MED by a cast saw, and MCD was measured along the MED axis (Fig. 1), since this distance was the smallest MCD of the pedicle. Measurement were taken using a vernier caliper and recorder to the nearest

tenth of a milimeter. A total of 2.808 measurements from 1.404 pedicle was made. The differance between MED and MCD was recrded as the cortical thicknesses (medial+lateral walls) of the pedicle.

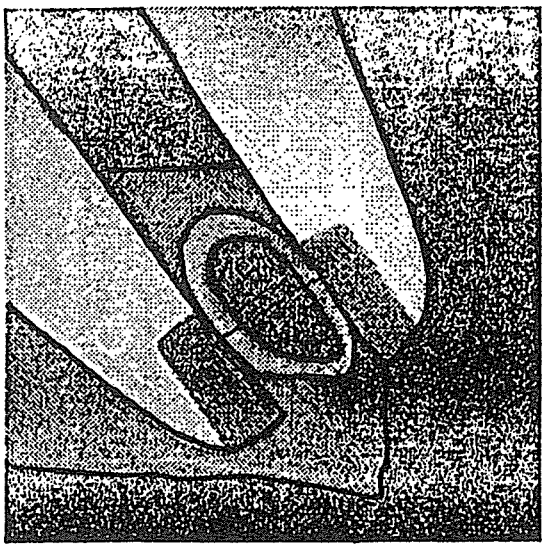

Figure 1. Posterior view and measurement of two diameters of a lumbar vertebra. MED, minimal cancellous diameter.

RESULTS

Descriptive statistics and ratios of pedicle diameters are given in Table 1. VD changed significantly ($p<0.01$) between thoracic and lumbar regions, while it was almost unchanged within the levels in each region. Td was similar between Th11 and L2, but increased $p<0.001$) between L2 and L5. The steady increase in MED from Th11 to L2 was nonsignificant ($p>0.05$), whereas to substantial increase from L2 to L5 was statistically significant ($p<0.01$) (Fig. 2). Minimal cancellous diameter was similar between Th11 and Th12 ($p>0.05$), and significantly different among Th12 L1, and L2 ($p<0.05$) and among L2, L3, L4 and L5 ($p<0.001$) (Fig. 2). Cortical thickness was almost unchanged from Th11 to L3, followed by a substantial increase from L3 to L5 (Fig. 2).

The proportion of MCD to VD increased linearly from Th11 to L5. The ratio of MCD to TD increased between Th11 and L1, remained unchanged between L3 and L5. The proportion of MCD to MED was heigher for L1, L2 and L3 levels than Th11, Th12, and L5 (Fig. 3).

Table 1. Means, standard deviations, and ratios of various pedicle measurements (minimum and maximum values are in parentheses)*

Level	No. of pedicles	VD±SD	TD±SD	MED±SD	MCD±SD	CT±SD	MCD÷VD (%)	MCD÷TD (%)	MCD÷MED (%)
Th11	148	15.8±1.6 (12.2–19.0)	8.2±1.5 (5.1–11.3)	7.2±1.5 (3.3–11.2)	5.1±1.1 (1.84–8.9)	2.1±0.4 (1.2–3.1)	32.2	62.2	70.8
Th12	172	16.0±1.7 (12.1–21.3)	8.2±1.6 (4.4–12.4)	7.5±1.6 (3.8–11.2)	5.2±1.2 2.6–8.2)	2.3±0.5 (1.3–3.7)	32.5	63.4	69.3
L1	190	14.8±1.4 (12.0–18.3)	7.9±1.8 (4.4–13.6)	7.5±1.7 (3.6–12.0)	5.5±1.2 (2.0–9.1)	2.0±0.4 (1.2–3.1)	37.1	69.6	73.3
L2	230	14.3±1.7 (5.9–19.1)	8.2±2.0 (3.5–17.2)	7.7±1.9 (3.5–14.5)	5.8±1.4 (2.6–11.7)	1.9±0.6 (0.9–3.1)	40.6	70.7	75.3
L3	262	14.3±1.4 (10.9–17.8)	9.2±2.1 (4.6–15.1)	8.4±1.7 (4.3–12.7)	6.4±1.3 (2.8–9.3)	2.0±0.5 (1.0–3.5)	44.7	69.6	76.2
L4	220	14.0±1.8 (9.0–19.3)	12.5±2.0 (6.2–20.1)	10.0±1.3 (5.0–13.3)	6.9±1.0 (3.5–10.7)	3.1±0.6 (1.7–4.3)	49.3	55.2	69.0
L5	182	14.5±1.9 (10.2–21.3)	18.0±2.4 (12.0–25.7)	11.3±1.6 (8.0–18.1)	8.1±1.3 (5.1–13.7)	3.2±0.5 (2.2–5.0)	55.9	45.0	71.6

* VD, vertical diameter; TD, transverse diameter; MED, minimal external diameter; MCD, minimal cancellous diameter; CT, cortical thickness.

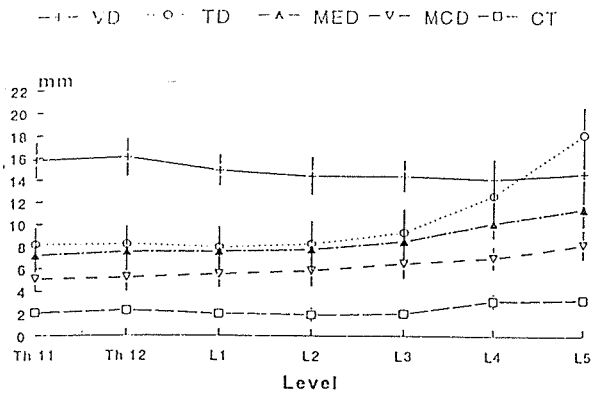

Figure 2. Various pedicle diameters and cortical thicknesses for each vertebral level.

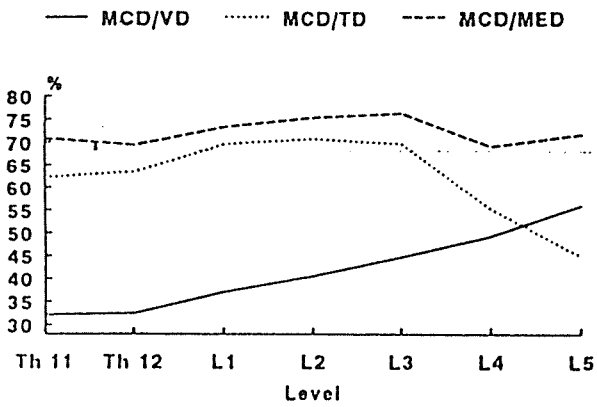

Figure 3. Rations of MCD to VD, TD and MED foor each vertebral level.

DISCUSSION

Since a majority of vertebral surgeries employ pedicular spinal fixation, a detailed knowledge of pedicular morphmetry and a perfect match between the screw and pedicle is very important (7, 11, 12, 22). There is a wealth of information about the external diameters of the pedicles (1, 2, 9, 12, 13, 14, 17, 18). Although the significance of the cancellous part of the pedicle has been indicated, there is a lack of information on the details of MCD. A detailed knowledge of MCD is vital because the selection of proper diameter of transpedicular screw is an important issue for safe surgical placement. Moran et al. (11) stated that "pedicle screws would be expected to obtain solid purchase in the cortical bone of the pedicle" and that "the screw threads might achieve better interlock with the compacted material". Therefor, diameter of the screw should be wider than the NCD and smaller than the MED. If the diameter of the screw is smaller than the MCD, the strenght of surgical fixation is reduced, and screw breakage may occur (8). On the other hand, if the diameter of the screw is larger than the MED, the pedicle may be broken or the thread cut out (6, 24).

Our findings show that proportions of mean MCD in the pedicle and in cortical walls were 71.6 and 28.4%, respectively. These findings agree with the results of Moran et al. (11), and which indicated that the pedicle was predominantly made up of the cancellous part, and with the results of Maillod and Wolfram-Gabel (9).

The increase in the ratio of MSD to VD between Th11 and L5 suggests that the amount of cancellous bone increases from thoracic to lomber regions while the amount of compact bone decreases. On the other hand, ratios of MCD to TD and MED are high in upper lumbar and lewer thoracic and lumbar levels (Table 1). This finding suggests that cancellous bone is low in lower thoracic and lower lumbar regions while compact bone is high. An examination of mean ratios reveals that the amount of cacellous bone is higher than compact bone in all levels, especially upper lumbar levels (L1, L2 and L3). It has been suggested by Pal et al. (13) that the pedicles between L1 and L3 are predominantly made up of thick compact bone, while the pedicles at the thoracic and lower lumbar region are predominantly made up of cancellous bone. Although this may seem to contradict our results, it is because the amount of cancellous bone in the entire pedicle was taken into account by Pal et al. (13).

In conclusion, to prevent mismatches between the screw and pedicle, and to establish proper spinal fixation, we recommended that estimation of MCD of the pedicle using TD, VD and MED be required for each level before operation. These results should also be used in the development of new implantable devices.

REFERENCES

1. Berry, J.L., J.M. Moran, W.S. Berg, and A.D. Steffee: A morphometric study of human lumbar and selected thoracic vertebrae. Spine, 12: 362-367, 1987.
2. Black, D.M., S.R. Cummings, K. Stone, E. Hudes, L. Palermo, and P. Steiger: A new approach to defining normal vertebral dimensions. J. Bone Min. Res., 6: 883-892, 1991.
3. Dick, W.: The "fixateur interne" as a versatil implant for spine surgery. Spine, 12: 882-900, 1987.

4. Dickman, C.A., R.G. Fessler, M. MacMillan and R.W. Haid: Transpedicular screw-rod fixation of the lumbar spine: operative technique and out come in 104 cases. J. Neurosurg., 77: 860-870, 1992.35
5. Güzel, M.B., B.U. Şakül, C. İslam, and S.K. Köse: A new method for differentiation of human lumbar vertebrae. Jekei Med. J., 41: 111-116, 1994.
6. İslam C., B.U. Şakül, M.B., Güzel: Real minimal diameter of the lower thoracic and lumbar vertebral pedicles. Clin. Anat., 7: 271-274, 1994.
7. Krag, M.H., B.D. Beynnon, M.H. Pope, J. W. Frymoyer, L.D. Haugh, and D.L. Weaver: An internal fixotor for posterior application to short segments of the thoracic, lumbar or lumbosacral spine. Clin. Orthop. Rel. Res. 203: 75-98, 1986.
8. Krag, M.H., D.L. Weaver, B.D. Beynnon, M.H. Pope, and L.D. Haugh: Morphometry of the thoracic and lumbar spine related to transpedicular screw placement for surgical spinal fixation. Spine, 13: 27-32, 1988.
9. Maillot, C and R. Wolfram-Gabel: Pedicles of lumbar vertebrae. Surg. Radiol. Anat., 15: 295-300, 1993.
10. Moore, K.L. Clinically Oriented Anatomy. Baltimore: Williams&Wilkins, pp. 576-579, 1985.
11. Moran, J.M., W.S. Berg, J.L. Berry, J.M. Geiger, and A.D. Steffee: Transpediculer screw fixation. J. Orthop. Res., 7: 107-114, 1989.
12. Olsewski, J.M., E.H. Simons, F.C. Kallen, F.C. Mendel, C.M. Severin, and D.R. Berens: Morphometry of the lumbar spine: Anatomical perspectives related to transpedicular fixation. J. Bone Joint Surg., 72A: 541-549, 1990.
13. Pal, G.P., L. Casino, and R.V. Routal: Trajectory architecture of the trabecular bone between the body and neural arch in human vertebrae. Anat. Rec., 222: 418-425, 1988.
14. Postacchini, F., M. Ripani, and S. Carpano Morphometry of the lumbar vertebrae: An anatomical study in two caucasoid ethnic groups. Clin Orthop. Rel. Res., 172: 296-303, 1983.
15. Roy-Camille, R., G. Saillant and C. Mazel: Internal fixation of the lumbar spine S with pedicle screw plating. Clin. Orthop. Rel. Res., 203: 7-17, 1986.
16. RoyCamille, R., G. Saillant and C. Mazel: Plating of thoracic and thoracolumbar and lumbar injuries with pedicle screw plates. Orthop. Clin. North Am. 17: 147-159, 1986.
17. Saillant, G: Anatomical study of vertebral pedicles: Surgical application. Rev. Chir. Orthop. 62: 151-160, 1976.
18. Saraste, H., L-A. Broström, T. Aparisi, and G. Axdorph: Radiographic measurement of the lumbar spine: Aclinical and experimental study in man. Spine, 10: 236-241, 1985.
19. Steffee, A.D., R.S. Biscup, And K.J. Sitkowski: Segmental spine plates with pedicle screw fixation. Clin. Orthop. Rel. Res. 203: 45-53, 1986.
20. Tortora, G.J. Principles of human anatomy. New York: Harper & Row, pp. 135-139, 1986.
21. Williams, P.L., R. Warwick, M. Dyson, and L.H. Bannister: Gray's Anatomy. Edinburgh: Churchill Livingstone, pp. 319-324, 1989.
22. Zindrick, M.R., L.L. Wiltse, E.H. Widell, J.C. Thomas, W.R. Holland, B.T. Fields, and C.W. Spencer: A biomechanical study of intrapeduncular screw fixation in the lumbosacral spine. Clin. Orthop. Rel. Res. 203: 99-112, 1986.
23. Zindrick, M.R., L. L. Wiltse, A. Doornik, E. H. Widell, G. W. Knight, A. G. Patwardhan, J. C. Thomas, S. L. Rothman, and B.T. Fields: Analysis of the morphometric characteristics of the thoracic and lumbar pedicles. Spine, 12: 160-166, 1987.